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The functional architecture of visual object recognition: cognitive and neuropsychological approaches

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During the period of this grant, we made progress on several issues related to visual object recognition. In keeping with our initial proposal, these issues primarily concerned face recognition, object recognition, printed word recognition, and their interrelations.

I. Face Recognition

In earlier ONR-funded work, 99 published case studies of face, object, and word recognition deficit were analyzed, and it was concluded that the range of different visual recognition deficits can be explained in terms of two (rather than three) different types of recognition ability (Farah, 1991). One of these abilities is required for face recognition, useful for object recognition, and not at all used for word recognition; the other is required for word recognition, useful for object recognition, and not at all used for face recognition. As our previous ONR-funded work on disorders of printed word recognition suggested, the latter ability is used when we must rapidly encode multiple visual shapes (Farah and Wallace, 1991). Words, being composed of multiple letters, tax this ability most heavily , but other objects are presumably encoded in terms of their parts also, and will thus also tax this ability to some degree.

On the basis of these observations, it was conjectured that face recognition might involve the encoding of complex shapes with little or no decomposition into parts. This conjecture was tested and confirmed in a series of experiments carried out under the present grant, and currently in press (Tanaka and Farah, 1992). In these experiments, we contrasted the ability of normal subjects to recognize faces and various non-face objects such as houses, either from the whole pattern or from a part.

Relative to the non-face objects, recognition of faces showed a disproportionately steep decline in going from whole to part.

During this grant period, we also tested an alternative theory of face perception, that of Diamond and Carey (1986). According to these researchers, face perception is special, and particularly susceptible to the effects of pattern inversion, because of its dependence on "second order relational properties." We noted that this claim had never been tested directly, and so we constructed a set of abstract stimulus materials (dot patterns) in which we could vary the salience and importance of second order relational properties for pattern recognition. In neither of two experiments were we able to find any greater susceptibility to inversion of the second order relational patterns (Tanaka and Farah,1991). A comparable test of the part/whole hypothesis of face recognition is currently underway.

II. Recognition of Living Things

Some brain-damaged patients seem to have more difficulty retrieving information about living things than about non-living things. In previous ONR-funded research, my colleagues and I made progress on several fronts in trying to understand this phenomenon and its implications for the functional architecture of the normal mind. Farah, McMullen, and Meyer (1991) attempted to separate out the effects of familiarity, complexity, name frequency, and numerous other factors determining recognition difficulty, on the ability of two such patients to recognize living versus non-living things. Much to our surprise, we found a robust living/non-living dissociation remained. Farah and McClelland (1991) showed, using a parallel distributed processing model, how a fundamentally modality-specific architecture could, when damaged, yield such apparently category-specific deficits.

Despite this work, the very existence of selective deficits in knowledge of living things remains controversial. Two recent studies have been published claiming that the difference in difficulty of retrieving knowledge about living and non-living things can account for the appearance of selective deficit. In each of these studies, various determinants of the difficulty of naming pictures were matched for living and non-living things and the previously observed dissociation was found to vanish. Farah, McMullen and Meyer (submitted) argue that these null effects are due to insufficient statistical power, and that knowledge of living things can indeed be selectively impaired. In support of this, we used the same stimulus materials, design, and data analysis as in one of

the articles, with two different brain-damaged subjects having the same etiology and general behavior, and show that: (1) when, like the authors of these articles, we use only a single replication of each item, no effect is found, and (2) when we use more replications of the same items, highly significant differences between living and non-living items emerge, for each of the two subjects.

III. The Relation between Visual Recognition and Awareness

Prosopagnosic patients appear to be impaired at recognizing faces. However, recent evidence for "covert recognition" in prosopagnosia has been taken to suggest that the impairment is not in face recognition per se, but rather in conscious access to face recognition. This implies that face recognition and awareness of face recognition depend on at least partly distinct components of the functional architecture, and indeed several authors have recently proposed models of visual recognition containing a "consciousness box". On the basis of empirical research with normal subjects and computer simulation, we propose an alternative hypothesis: that the visual recognition system in these patients is damaged but not obliterated, and that it is an intrinsic property of damaged neural networks that they will manifest their residual knowledge *in just the kinds of tasks used to measure covert recognition.*

The most widely used test for covert recognition of faces in prosopagnosia is the face-name relearning task, in which some prosopagnosics have been found to learn correct names for previously familiar faces more easily than incorrect names. Although this phenomenon is consistent with face recognition operating normally, but out of reach of conscious awareness, it may also be consistent with impairment of face recognition per se. Perhaps savings and relearning is sufficiently sensitive to the residual information contained in degraded face representations that are not detectable by overt measures of recognition. If so, then we should expect to observe this same savings and relearning when overt recognition is obliterated for reasons other than brain damage. Wallace and Farah (1992) used forgetting of face-name associations in normal subjects as a way of degrading recognition ability. We found the same association between overt recognition performance and savings and relearning as observed in prosopagnosic patients. This implies that the performance of prosopagnosic patients in these tasks does not demand explanation in terms other than an impairment in face recognition per se.

Farah, O'Reilly and Vecera (submitted) simulated savings and relearning and two other tasks used to tap covert recognition, as well as overt recognition tasks. When the simulation model was damaged, even when the damage was confined to parts of the model corresponding to visual processing of faces, a dissociation emerged between overt and covert recognition. Specifically, at levels of damage yielding overt recognition performance comparable to patients described in the literature, the model demonstrated covert recognition in three different tasks: savings and relearning, semantic priming, and perceptual speed. This demonstration adds computational evidence to the hypothesis that covert recognition of faces in prosopagnosia reflects a damaged but not obliterated face recognition system. It thus counts against the hypothesis that visual recognition and awareness of recognition depend upon distinct components of the architecture.

IV. Visual Imagery, and Visual Attention

A fundamental issue about visual imagery, and the subject of much controversy, is whether visual imagery makes use of some of the same representations in the visual system as visual perception. In earlier ONR-funded research, summarized in Farah (1989), I marshaled neuropsychological evidence to address this issue. Recently, we were fortunate to encounter an exceptionally interesting patient, who afforded the possibility of a critical experiment to determine the role of early, occipital visual areas in mental imagery. Farah, Soso, and Dasheiff (1992) tested an exceptionally high-functioning young woman, whose epilepsy had made her a candidate for a unilateral occipital lobectomy. By assessing the maximum visual angle of her mental images before and after surgery, we were able to determine whether the spatially-mapped representational medium of the occipital lobes plays a role in imagery as well as in perception. We found that her maximum image size was reduced following surgery, particularly in the horizontal dimension, consistent with the hypothesis that mental images are represented in the occipital lobes.

Using computer simulation, Cohen, Romero, and Farah (submitted) tested and confirmed the hypothesis that a single attentional mechanism could underlie both the engaging and disengaging of visual attention. We built and lesioned a simple model of visual-spatial attention, and found that we could produce a "disengage" deficit after unilateral attention unit lesions, even though there was no component in the model corresponding to a "disengager." This suggests that the functional architecture of visual attention may be simpler than it first appeared, on the basis of Posner's early studies of parietal-damaged patients.